Application of hierarchical clustering method to classify space-time rainfall patterns

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Introduction

Understanding spatiotemporal variability of rainfall events is an important and frequent practice in hydrology for myriads of purposes, such as water resources management and flooding mitigation.

Different spatiotemporal rainfall patterns can result from different mechanisms of genesis of meteorological and atmospheric processes

Our study investigates the common spatiotemporal patterns in Ilan county (Taiwan) which can provide the insights of primary rainfall mechanisms and their associated impacts of the study area.

Spatiotemporal rainfall classification

Considering the seasonality, *K*-Means algorithm is used to distinguish the four seasons. Our proposed classification technique is then applied to the spatiotemporal rainfall clustering by analyzing rainfall events lasting.

Hierarchical clustering (HC) method is used which classifies rainfall events according to the discrepancy measure, i.e. Ward criterion, which maximize the “distance” among the classes of space-time rainfall events. The Euclidean distance is used and expressed as

$$D(P_t,P_{t'})=\sqrt{\sum_{i=1}^{N} W_i\left[P_{ti}-P_{t'i}\right]^2}$$

✓ $P_t=(P_{t1},\ldots,P_{tN})$ is the rainfall characteristics at time t and rainfall station i among N weather stations, and can be represent as the form of $P_{ti}=(R_{ti},Sa_{ti},Ta_{ti})$

✓ R_{ti} is the observed daily rainfall at .

✓ Sa_{ti} and Ta_{ti} are the spatial and temporal rainfall anomalies, respectively, defined by

$$Sa_{ti}=R_{ti}-1/N\sum_{i=1}^{N}R_{ti}$$

$$Ta_{ti}=R_{ti}-1/T\sum_{i=1}^{N}R_{ti}$$

✓ W_i is the weight which is used to discern the extreme events which frequently occur in the study area

$$W_i=(P_{ti}+P_{t'i})^n/\sum_{i=1}^{N}(P_{ti}{}^n+P_{t'i}{}^n)$$

✓ n is scaling parameter for adjusting the variation of rainfall.

Materials sources

Study area: Ilan county located at northeast Taiwan, attached to The Central Mountains and faced Pacific Ocean with an area of approximately 2,143 km^2,

- ✓ Major rainfall mechanisms:
  - ➢ Northeastern monsoon in winter
  - ➢ Meiyu in later spring and early summer
  - ➢ Typhoon are active frequently.
- ✓ Annual rainfall: approximately 2827 mm

Definition of a rainfall event:

- ✓The start of a rainfall event while any of the thirteen stations starts to record rainfalls.
- ✓The rainfall events lasting from 1 days to 6 days are considered.

Study period: 1989 to 2008

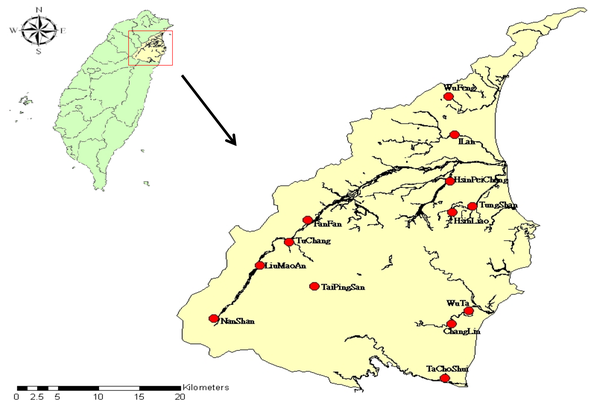


Table 1:Locations and characteristics for rainfall stations

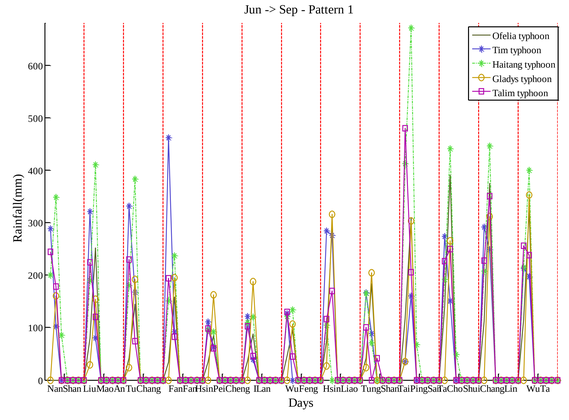
Site	Lon. (◦E)	Lat. (◦N)	Elev. (m)	Aspect
NanShan	121.37	24.44	1050	Northeast
LiuMaoAn	121.44	24.53	585	Northeast
TuChang	121.49	24.57	400	Northeast
FanFan	121.52	24.61	295	Northeast
HsinPeiCheng	121.74	24.68	16.5	Northeast
ILan	121.75	24.77	7.2	East
WuFeng	121.74	24.83	83	Southeast
HsinLiao	121.74	24.63	60	Northeast
TungShan	121.78	24.64	5	Northeast
TaiPingSan	121.53	24.5	1930	Southeast
TaChoShui	121.73	24.33	48	Southeast
ChangLin	121.74	24.43	160	Southeast
WuTa	121.77	24.45	32	Southeast

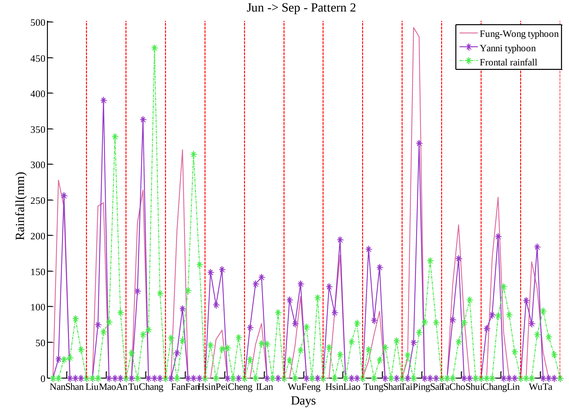
Results

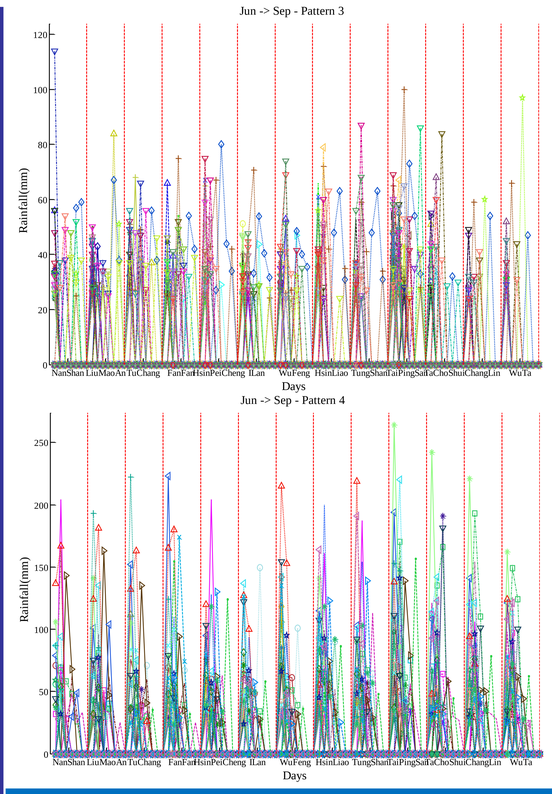
Table 2: Cophenetic correlation coefficients (CCs) and Spearman’s rank correlation coefficients (SRCs) of four seasons are lie in between 0.70 and 0.881

Correlation coefficient	March ~ May	June ~ September	October ~ November	December ~ February
CCs	0.743	0.881	0.841	0.714
SRCs	0.70	0.857	0.861	0.753

Figure 1: The summer (June ~ September) is classified to four patterns.







Conclusion

- ➢HC can effectively classify the space-time patterns among the rainfall events
- ➢In Ilan county (Taiwan), the summer (June ~ September) is classified into four patterns by HC.
  - Pattern1 was caused by five typhoons (Ofelia, Tim, Haitang, Gladys, Talim), which went across the Taiwan island.
  - Pattern 2 was caused by two typhoons (Fung-Wong, Yanni) which passed by the East part of Taiwan island and a frontal rainfall (while a typhoon was attacking Hong-Kong).
  - In pattern 3, rainfall generally stretched from the downstream to the upstream, which may result from stratiform rainfall.
  - Pattern 4 shows rainfall generally started at mountain areas and then extended to the ocean side, which may the result of convective rainfall.